ALASKA OREGON WASHINGTON
PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION

USDA FOREST SERVICE RESEARCH NOTE

PNW-165 *September 1971*

GROWTH OF YOUNG EVEN-AGED WESTERN LARCH STANDS AFTER THINNING IN EASTERN OREGON

by

K. W. Seidel, *Silviculturist*

ABSTRACT

The 5-year growth response of a 33-year-old pure even-aged western larch stand thinned to a wide range of stocking levels was measured in eastern Oregon. Both basal area and volume growth increased as stand density increased, with volume growth increasing from a low of 64 cubic feet per acre annually at the lowest density to 133 cubic feet at the highest density.

Despite the large reduction in volume increment at the lowest density, there was a substantial transfer of growth from many slowly growing trees to a lesser number of faster growing ones. Ninety-six trees at the lowest density produced approximately half as much wood as 745 trees at the highest density. Diameter growth at the lowest density level was sharply increased over that at the higher levels.

Keywords: Stand density, thinning (trees), forest measurement, stand increment estimates, western larch, *Larix occidentalis*.

Western larch (*Larix occidentalis* Nutt.) is an important species in the forests of the Blue Mountains of northeastern Oregon growing in both pure and mixed stands. According to a 1963 forest survey, there are about 400,000 acres on which larch is the predominant species in eastern Oregon, and about 38,000 acres are occupied by pole-sized stands.[1]

[1] Donald R. Gedney. Toward complete use of eastern Oregon's forest resources. Portland, Oreg., Pac. Northwest Forest & Range Exp. Sta. USDA Forest Serv. Resour. Bull. PNW-3, 71 p., illus., 1963.

Although utilization of this species is increasing, there is little growth and yield information available from managed stands to aid the forest manager in thinning operations in pole-sized stands.

In 1966, a study designed to provide basic information on the response of pure even-aged larch stands to a wide range of stocking levels was begun in northeastern Oregon. This interim report covers the first 5-year period of the study.

STUDY AREA AND METHODS

The study is located on the Union District of the Wallowa-Whitman National Forest about 15 miles southeast of Union, Oregon, at an elevation of about 4,000 feet. The stand was 33 years old when first thinned in 1966 and has a site index of about 80 feet at age 50.[2] The soil is classified as a Tolo silt loam, which is a well-drained regosol developed from dacite pumicite originating from the eruption of Mount Mazama (Crater Lake) 6,500 years ago. It is underlain at a depth of about 3 feet by a buried soil developed from basalt.

Many shrubs and herbs typical of the *Abies grandis/Calamagrostis rubescens* habitat type such as pinegrass (*Calamagrostis rubescens* Buckl.), heartleaf arnica (*Arnica cordifolia* Hook.), white hawkweed (*Hieracium albiflorum* Hook.), and *Ribes* spp. are found on the study area.[3]

Ten 0.4-acre plots were located in the study area and five levels of stocking were created by thinning. Each level was replicated two times. The density measure used in this study is bole area, which is the cambial area of the main stem. For those not familiar with bole area, corresponding densities in terms of basal area are also given. The five bole area levels used in this study are 5,000, 10,000, 15,000, 20,000, and 25,000 square feet per acre. Plots will be rethinned according to the same density levels every 10 years. On two of the 10 plots (one at the 25,000- and one at the 20,000-square-foot level), about 40 percent of the bole area and basal area left after thinning was lodgepole pine (*Pinus contorta* Dougl.).

In general, plots were thinned from below, the objective being to leave the required number of the best trees as evenly spaced as possible over the plot (fig. 1). None of the slash from the thinning was removed from the plots.

---

[2] Site index based on curves in "Ecology and Management of Western Larch," by Arthur L. Roe, Raymond C. Shearer, and Wyman C. Schmidt, USDA Tech. Bull., in preparation.

[3] For a discussion of the habitat types in the *Abies grandis* zone in the Blue Mountains, see "Vegetation of Oregon and Washington," p. 129-134, by Jerry F. Franklin and C. T. Dyrness, USDA Forest Serv. Res. Pap. PNW-80, Pac. Northwest Forest & Range Exp. Sta., Portland, Oreg., 1969.

Figure 1.—One of the 10,000-square-foot bole area density plots after thinning, with an average spacing of 14 feet. Basal area is about 50 square feet per acre.

All plots were well stocked before treatment, each containing at least 25,000 square feet of bole area per acre (table 1). Trees were spaced about 5.5 to 7 feet apart and average diameter was about 4.5 inches.

Diameters of all plot trees were measured to the nearest one-tenth inch in 1966 and 1970. On each plot, about 15 trees covering the range of diameters present were measured with an optical dendrometer in 1966 and 1970 for the purpose of calculating an equation expressing volume and bole area of the entire stem as a function of diameter for each plot. These equations were used to compute plot volumes and bole areas. A new equation was calculated for each period. Height growth was measured by dendrometer on those trees chosen for volume equation measurements. Analysis of variance and Duncan's multiple range test were used to test the significance of treatment effect. The word "significant" when applied to treatment effects indicates statistical significance at the 5-percent level.

Table 1.--*Stand characteristics per acre of western larch before and after 1966 thinning and 5 years later*

Density level	Bole area	Basal area	Number of stems	Average spacing	Average diameter[1/]	Average height[2/]	Volume[3/]		
							Total	Merchantable including ingrowth	
	Square feet			*Feet*	*Inches*	*Feet*	*Cubic feet*		*Board feet*
Before initial (1966) thinning:									
1	25,800	118.6	924	6.9	4.9	48.4	1,995	1,180	48
2	31,125	132.7	1,161	6.1	4.6	46.2	2,287	1,088	--
3	34,180	139.2	1,406	5.6	4.3	46.5	2,367	885	193
4	32,880	143.7	1,377	5.6	4.4	42.9	2,322	1,125	--
5	32,700	135.6	1,459	5.5	4.1	42.0	2,200	964	--
After thinning:									
1	4,708	26.0	96	21.3	7.0	48.4	474	389	48
2	9,524	49.6	215	14.2	6.5	46.2	902	648	--
3	14,242	70.9	355	11.1	6.1	46.5	1,272	782	193
4	19,313	96.4	546	8.9	5.7	42.9	1,616	1,039	--
5	24,203	109.8	745	7.6	5.2	42.0	1,847	961	--
1971:									
1	6,374	40.3	96	21.3	8.8	55.4	794	678	948
2	12,069	68.2	215	14.2	7.6	51.7	1,333	1,060	294
3	17,797	93.4	354	11.1	7.0	53.3	1,780	1,261	532
4	23,810	120.5	539	9.0	6.4	49.1	2,250	1,562	345
5	29,121	134.3	740	7.7	5.8	48.0	2,510	1,435	102
Thinning yield:									
1	--	--	828	--	--	--	1,521	791	--
2	--	--	946	--	--	--	1,385	440	--
3	--	--	1,051	--	--	--	1,095	103	--
4	--	--	831	--	--	--	706	86	--
5	--	--	714	--	--	--	353	3	--

1/ Diameter of the tree of average basal area.

2/ Average height of trees measured with dendrometer (about 15 per plot).

3/ Total cubic-foot volume--entire stem, inside bark, all trees.
Merchantable cubic-foot volume--trees 5.0-inch d.b.h. and larger to a 4-inch top d.i.b.
Board-foot volume--International 1/4-inch scale, trees 10.0-inch d.b.h. and larger to a 6-inch top d.i.b.

RESULTS

Individual Tree Growth

Diameter growth.--Trees grew fastest in diameter on the plots with the lightest stocking (fig. 2). Each reduction of 5,000 square feet of bole area resulted in a significant increase in diameter growth, and the average growth of all trees at the lowest density (0.36 inch per year) was more than three times the growth at the highest density (0.11 inch per year).[4]

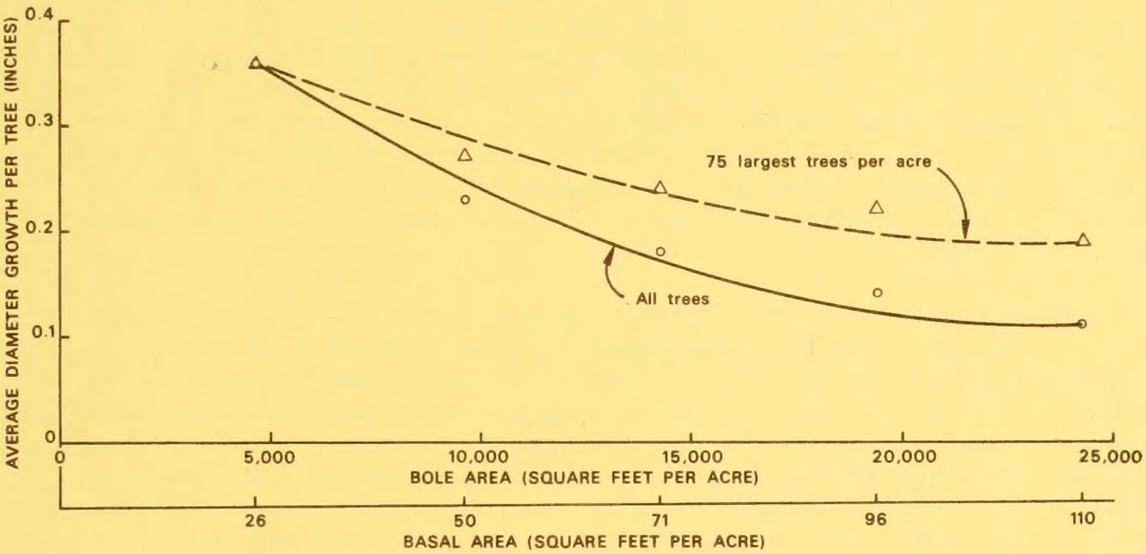

Figure 2.–Relation between density after thinning and periodic annual diameter growth.

Comparison of diameter growth of the 75 largest diameter trees per acre with growth of all trees shows the largest trees in each density level grew the fastest (fig. 2). At the highest density, diameter growth of the 75 largest trees per acre (0.19 inch) is almost twice as much as that of all trees (0.11 inch). This difference becomes more pronounced as bole area increases because of more smaller, slower growing trees in the denser plots. Also, diameter growth of the largest trees in a stand is affected by increasing stand density in the same manner as is growth of all trees; growth dropped from 0.36 inch at the low bole area level to 0.19 inch at the high density because of the greater competition of additional trees. In other words, even though the largest trees in the stand are the most vigorous and occupy the most favorable position, they are not independent of stand density with respect to diameter growth.

[4] Ratios of wood to bark were not significantly different among any of the treatments at either measurement nor was there any significant change in ratios between the two measurements. Therefore, differences in bark growth are not involved in the diameter growth data.

There was little difference in average diameter growth between larch and lodgepole. At the highest density level, larch grew 0.114 inch per year and lodgepole, 0.118 inch. At the second highest level, diameter growth of larch was slightly greater than that of lodgepole (0.142 vs. 0.128 inch per year). These were the only two levels containing lodgepole pine.

Height growth.--There was no significant effect of stand density on total height growth, nor was there any indication that total height growth was correlated with density. Trees grew an average of 5.6 to 7.0 feet in total height (table 2), and growth of individual trees ranged from 0.6 foot to 11.7 feet during the 5-year period. As might be expected, there was a consistent increase in total height growth with tree diameter at all density levels except the two largest diameter classes at the lowest density. This is the same relationship found for diameter growth and simply means that in a young even-aged stand, the largest trees grow the fastest--in both diameter and height--because they are the most vigorous trees in the best competitive position.

When considering merchantable height growth to a 4-inch top diameter inside bark, density was found to have a significant effect. This was due entirely to the significant increase in merchantable height of trees in the lowest density plots compared with the other levels. The greatest increase in merchantable height (11 feet) occurred in the 5- and 6-inch diameter classes at the lowest density, almost twice as much as in the same diameter classes at the highest density (table 2). This greater merchantable height growth at the lower density is not due to greater total height growth (since it varies little by density) but to increased diameter growth along the entire length of the bole of trees in the low-density plots. For example, the average 5-year diameter growth at a height of 30 feet of 5- and 6-inch trees at the lowest density was 1.3 inches, but at the highest density it was only 0.6 inch.

In the two plots containing both larch and lodgepole, there was almost no difference in total height growth between the two species. On one plot, larch height growth averaged 5.9 feet and lodgepole, 5.6 feet; on the other plot, larch grew 5.6 feet and lodgepole, 5.7 feet during the 5 years.

Stand Growth

Basal-area growth.--Gross basal area increment increased from 2.86 to 5.07 square feet per acre per year as stocking increased from the lowest to highest level (fig. 3). The greatest increase in growth occurred as stand density rose from 5,000 to 15,000 square feet of bole area (or from 26 to 71 square feet of basal area). At densities greater than 15,000 square feet of bole area, growth was relatively uniform.

Table 2.--*Average total and merchantable height growth from 1966 to 1971 by initial diameter class and density level*

Density level and 1966 diameter class	5-year height growth	
	Total	Merchantable[1]
	---Feet---	
1 (low):		
5-6 inches	6.4	11
7-8 inches	7.3	9
9-10 inches	7.1	8
Average	6.9	9
2:		
3-4 inches	4.4	--
5-6 inches	5.4	9
7-8 inches	6.1	7
9-10 inches	6.5	6
Average	5.6	7
3:		
3-4 inches	5.6	--
5-6 inches	6.5	7
7-8 inches	7.2	6
9-10 inches	8.7	7
Average	7.0	7
4:		
3-4 inches	5.8	--
5-6 inches	6.2	7
7-8 inches	6.3	6
9-10 inches	7.8	6
Average	6.5	6
5 (high):		
3-4 inches	4.6	--
5-6 inches	5.7	6
7-8 inches	6.6	7
9-10 inches	7.6	7
Average	6.1	7

[1] Merchantable height to 4-inch top d.i.b.

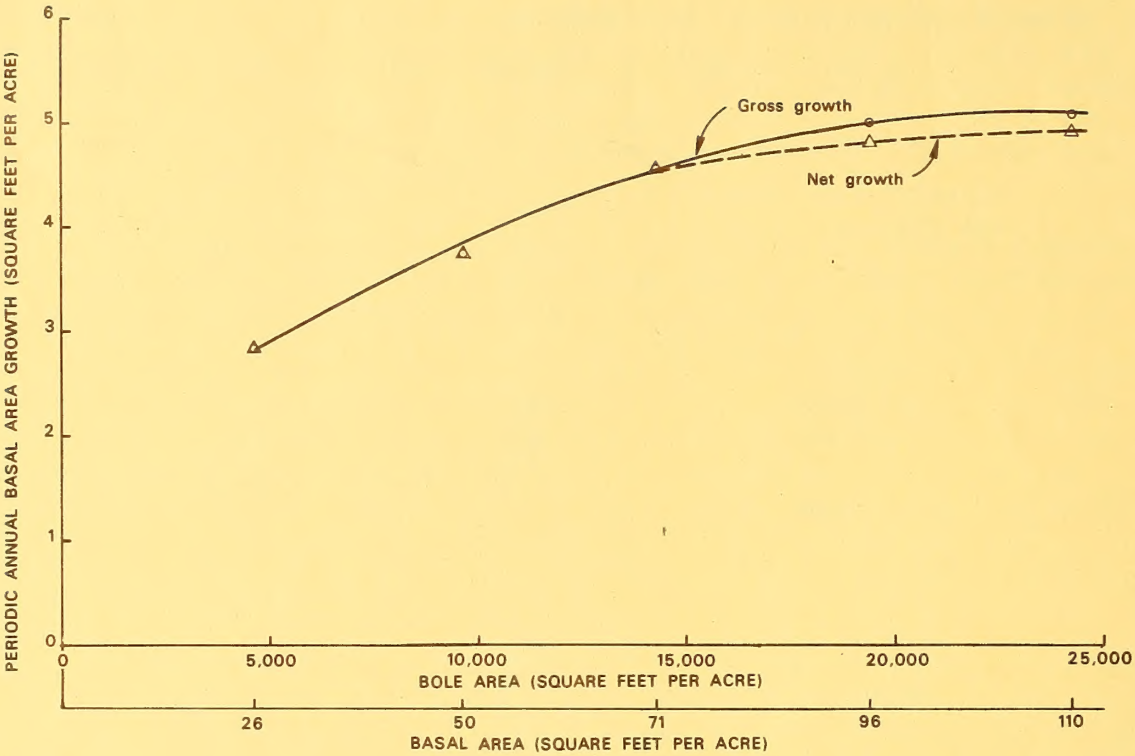

Figure 3.—Relation between density after thinning and periodic annual basal area growth.

Basal area accumulated most rapidly per unit of initial basal area at the lowest density level (increasing to 1.6 times its initial amount), where diameter growth was the greatest. At the highest stocking level, the increase was 1.2 times the initial base. Thus, even though basal area accumulated more rapidly per unit of initial basal area at the lowest level, the 5-year increment was greatest at the highest density because of the larger base of growing stock.

Because of the small amount of mortality on these plots (only 12 of 1,567 trees died), net basal area increment is essentially the same as gross growth except for a slight decrease at the higher densities where the mortality occurred.

Volume growth.--Total gross volume increment was affected by stand density in the same manner as was basal area increment, volume growth increasing from 64 cubic feet per acre per year at the lowest stocking level to 136 cubic feet per acre per year at the highest density (fig. 4). Mortality was only 3 cubic feet per acre per year (table 3) in the high density stand, so total net increment was only slightly less than gross growth as basal area stocking became greater than 70 square feet per acre. Any increase of 10,000 square feet of bole area resulted in a

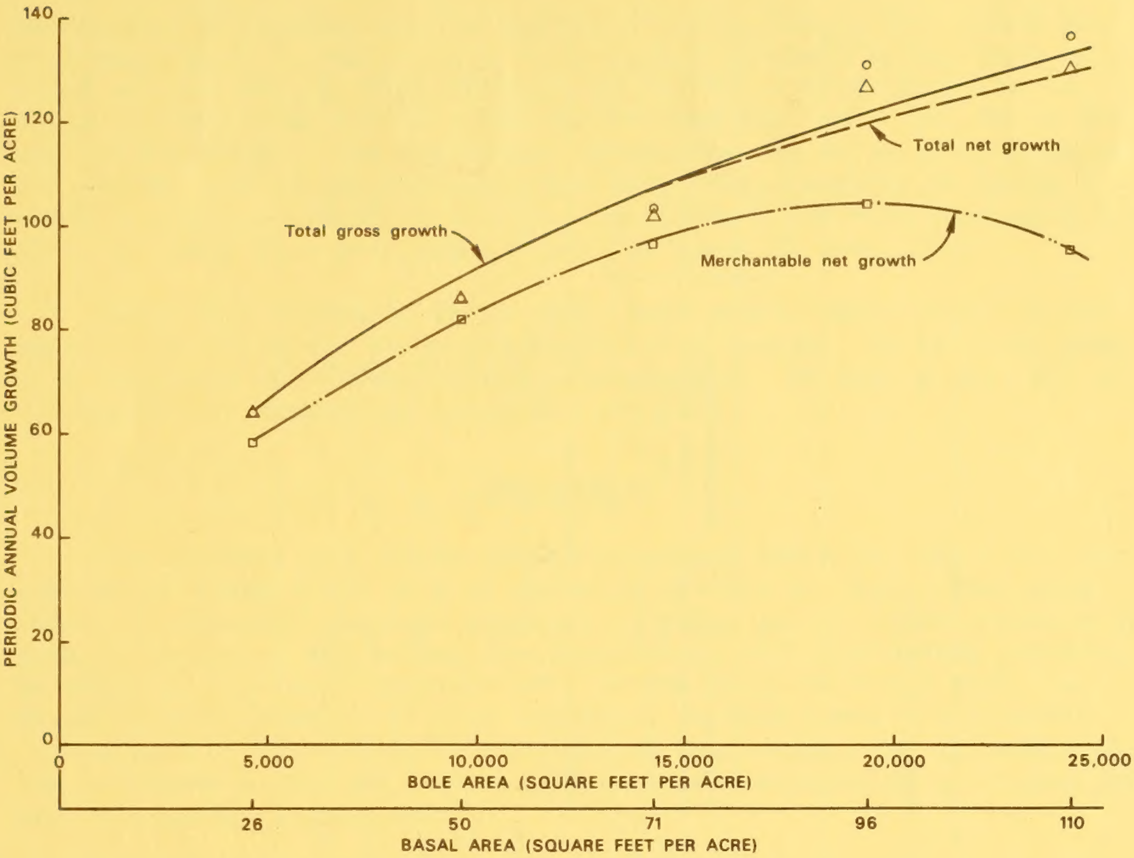

Figure 4.—Relation between density after thinning and periodic annual volume growth.

significant rise in total volume increment. Increases from 5,000 to 10,000 and from 15,000 to 20,000 square feet of bole area also resulted in significant increases in volume growth.

When merchantable growth in trees 5.0-inch d.b.h. and larger to a 4-inch top is considered, the results are somewhat different. Here, each density increase resulted in a significant increase in merchantable volume increment until bole area reached 15,000 square feet (fig. 4). The next increase in density caused a continued rise in volume growth, followed by a reduction in growth at the highest stocking level. Therefore, smaller trees under 5-inch d.b.h. account for a considerable amount of the total volume growth at the highest density.

In terms of total volume growth, figure 4 illustrates that the full productive capacity of the site has not been utilized since growth continued to increase at each density level. However, full site utilization would probably be reached at a stand density not much greater than 110 square feet of basal area since the growth curve showed a tendency to level off at the upper stocking levels. Although maximum total wood

Table 3.--*Periodic annual growth and mortality per acre of western larch stands after initial thinning at age 33*

Density level	All trees											75 largest trees	
	Residual density		Diameter growth	Basal area growth			Total volume growth			Merchantable net volume growth including ingrowth		Diameter growth	Gross total volume growth
	Bole area	Basal area		Net growth	Mortality	Gross growth	Net growth	Mortality	Gross growth				
	---*Square feet*--		*Inches*	-------*Square feet*-------			--------*Cubic feet*-------			*Cubic feet*	*Board feet*	*Inches*	*Cubic feet*
1	4,700	26.0	0.36	2.86	--	2.86	64	--	64	58	180	0.36	54
2	9,500	50.0	.23	3.72	--	3.72	86	--	86	82	59	.27	40
3	14,250	71.0	.18	4.50	.03	4.53	102	1	103	96	68	.24	31
4	19,300	96.0	.14	4.82	.19	5.01	127	4	131	104	69	.22	30
5	24,200	110.0	.11	4.90	.17	5.07	133	3	136	95	22	.19	28

production is attained at the highest stocking level, the volume is, of course, distributed among a large number of small trees, many of which are not usable. In contrast, at the lower basal area levels there is some reduction in total production, but the growth is on fewer and larger trees. Thus individual trees grow faster in both diameter and volume, permitting shorter rotations. This is shown in table 3 where the volume growth of the 75 largest trees per acre increased from 28 to 54 cubic feet per acre per year as stocking decreased.

Board-foot growth in these young pole stands means little since most of the trees are below merchantability limits. It is shown only as a reference for future growth measurements. On most plots, all of the board-foot growth was ingrowth.

DISCUSSION

The diameter and volume growth responses found in this study are typical of those found in most thinning studies of young, even-aged stands. Generally, in such studies, diameter growth slows markedly as density increases and volume increment rises with increasing stocking or remains relatively constant over a wide range of stand densities. Height growth response is more variable, in some cases being rather insensitive to changes in density, as in this study, and in others showing increased growth as a result of thinning, especially if stands had been extremely overstocked.

Decisions concerning thinning intensity depend upon many factors such as number of years between thinnings, average stand diameter, rotation age, present and future markets for small trees, and multiple-use considerations involving water yield, forage, wildlife habitat, or esthetic values. Obviously, firm recommendations for thinning intensity in larch stands in eastern Oregon cannot be made from a base of only 5 years of data from a single study. However, for young stands on good sites such as these, some general observations seem appropriate. If markets for small trees are available, if frequent thinnings are possible, and if the management objective is to maximize wood production, then a high residual stand density is suggested in order to more fully utilize the productive potential of the site. On the other hand, if no pulpwood market exists, if thinning cycles are long, and if the land is managed under multiple-use objectives, then a heavier initial thinning is indicated.

Using the results of this study and certain necessary assumptions, an estimate can be made of the stocking to leave after the first thinning where there is no pulpwood market. The following assumptions will apply:

1. The initial thinning will be a precommercial thinning designed to achieve a rapid enough diameter growth rate on the residual trees so that a commercial thinning may be made at the next entry.

2. The second (commercial) thinning will be made 20 years after the initial thinning, and at this time all trees removed must be merchantable (at least 10.0-inch d.b.h.).

3. Basal area increment will continue at about the present rate during the 20-year period since the increased rate from rising stand density will be offset by a falling rate expected with greater age.

4. Little mortality will occur during the 20 years.

Under these conditions, the average stand diameter 20 years after the initial thinning can be estimated by adding the basal area growth during the period to the basal area present after thinning and computing average diameter as the diameter of the tree of mean basal area. Table 4 shows the estimated change in average diameter of the three lowest density levels. In order to have all trees reach a diameter of 10 inches 20 years after the first thinning, the average stand diameter would have to be about 12 inches. In the example given, this would require leaving about 120 trees per acre at an average spacing of about 19 feet.

It should be emphasized that this decision is based on the facts and assumptions used in this example. Some foresters will very likely use different assumptions. However, as it is important to recognize that trees should be merchantable at the time of the next thinning, the spacing selected for the initial thinning should take this requirement into account.

Table 4.--*Estimated change in basal area and average diameter per acre of larch stands 20 years after thinning to three density levels*

Density level	Number of stems		Annual basal area growth	Basal area		Average diameter	
	1966	1986		1966	1986	1966	1986
			-------*Square feet*-------			*Inches*	
1	96	96	2.8	26	82	7.0	12.5
2	215	215	3.7	50	124	6.5	10.3
3	355	355	4.4	71	159	6.1	9.1